Marine Physical Laboratory

DURIP - Mid-Frequency Source-Receive Array

Principal Investigator(s) William S. Hodgkiss

Supported by the
Office of Naval Research
Grant Number: N00014-01-1-0799

Final Report

June 2003

University of California, San Diego
Scripps Institution of Oceanography

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. Agency Use Only (Leave Blank).	2. Report Date. July 9, 2003	3. ReportType and Dates Covered. Final Report

4. Title and Subtitle.
DURIP - Mid-Frequency Source-Receive Array

5. Funding Numbers.
N00014-01-1-0799

Project No.
Task No.

6. Author(s).
William S. Hodgkiss

7. Performing Monitoring Agency Names(s) and Address(es).
University of California, San Diego
Marine Physical Laboratory
Scripps Institution of Oceanography
291 Rosecrans Street
San Diego, CA 92106

8. Performing Organization Report Number.

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Office of Naval Research
Department of the Navy
800 North Quincy Street
Arlington, VA 22217-5660
Atten: CDR J. Tague

10. Sponsoring/Monitoring Agency Report Number.

11. Supplementary Notes.

12a. Distribution/Availability Statement.
Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract (Maximum 200 words).
A mid-frequency (~850 Hz) source-receive array has been fabricated for use in demonstrating enhanced operation of offboard active surveillance systems using phase conjugation (time reversal "mirror") concepts. The source-receive array and its companion surface buoy operate in an autonomous fashion thus facilitating single ship operations for carrying out experimental work. The equipment needed for system fabrication was supported by this DURIP. The personnel support for system fabrication was provided separately under grant N00014-01-1-0794.

14. Subject Terms.
mid-freuqncy source array, transducers

15. Number of Pages.
10

16. Price Code.

17. Security Classification of Report	18. Security Classification of This Page.	19. Security Classification of Abstract.	20. Limitation of Abstract.
Unclassified	Unclassified	Unclassified	None

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

DURIP: Mid-Frequency Source-Receive Array
N00014-01-1-0799

W.S. Hodgkiss

Marine Physical Laboratory
Scripps Institution of Oceanography
La Jolla CA 92093-0701

Abstract

A mid-frequency (~850 Hz) source-receive array has been fabricated for use in demonstrating enhanced operation of offboard active surveillance systems using phase conjugation (time reversal "mirror") concepts. The source-receive array and its companion surface buoy operate in an autonomous fashion thus facilitating single ship operations for carrying out experimental work. The equipment needed for system fabrication was supported by this DURIP. The personnel support for system fabrication was provided separately under grant N00014-01-1-0794.

Time Reversal Mirror Concept

A phase conjugate mirror time reverses the incident signal precisely returning it to its original source location. This phenomenon occurs independent of the complexity of the medium. The time reversal process can be accomplished by the implementation of a retransmission procedure (see Fig. 1). A signal received at an array is time reversed and retransmitted. A source array excited by the phase conjugated (time reversed) signal received at the array position will focus at the position of the radiating source. The medium fluctuations are embedded in the received signal so that if retransmission can occur on a time scale less than the dominant fluctuations, the medium variability will be eliminated since one back propagates and "undoes" the variability.

Source-Receive Array System Description

The mid-frequency source-receive array system is an enhancement of existing electronics and surface buoy hardware from a previously-funded (FY98) DURIP which focused on high frequencies (~3.5 kHz). The existing high frequency system has been upgraded so that it can operate at both 850 Hz and 3.5 kHz.

The high frequency phase conjugation array consists of a vertical array of 29 source/receive transducers operating nominally in the 3-4 kHz band, an underwater pressure case containing the source/receive electronics, and a surface buoy providing battery power, system control, and wireless local area network (LAN) connectivity (see Fig. 2)) [1]. The upgraded system has the same general configuration with an array of 850 Hz transducers replacing the array of 3.5 kHz transducers.

Mid-Frequency Source-Receive Array Fabrication

Fabrication of the mid-frequency source-receive array involved acquiring mid-frequency (~850 Hz) transducers to populate the 29-element array (plus spares), calibrating their transmit (TVR) and receive (FFVS) characteristics, and making appropriate modifications to the existing electronics packaging inside the pressure case to accommodate new transformers enabling operation of the power amplifiers at both 850 Hz and 3.5 kHz. The fundamental design of the source/receive electronics in the pressure case and the surface buoy hardware have remained unchanged and are described in detail in [1].

Note that an integrated array cable with molded take-outs was included in the original proposal. Permission was requested to substitute the purchase of a new steel armored umbilical cable connecting the pressure case and surface buoy. Testing of the existing umbilical cable showed it to be unreliable. In place of the integrated array cable, the original approach of using individual coaxial cables (bundled with spiral wrap) connecting the transducers to the pressure case was continued.

A significant amount of effort was spent calibrating the transducers and interacting with the transducer manufacturer (Marine Acoustics Limited). Although a standard transducer in their product line, the MAL Sonoflex 850 transducers proved problematic. The original set of transducers which were delivered failed their acceptance test with substantial deviations from the advertised specifications in both source level and resonance frequency. MAL was responsive and subsequently supplied a replacement set of transducers. The measured calibration characteristics of these transducers (both transmit (TVR) and receive (FFVS)) are provided in Figs. 3-6. Note the substantial variation in resonance characteristics across the set of transducers at a common depth (Figs. 3-4) and for a given transducer as a function of depth (Figs. 5-6). At the nominal TVR specification of 131 dB re 1 μPa/V, each transducer of the mid-frequency source-receive array has a maximum output source level of 189 dB re 1 μPa.

The mid-frequency transducers were assembled into a source-receive array and taken to sea during the FAF-03 (Focused Acoustic Fields 2003) experiment sponsored separately by the Office of Naval Research and carried out jointly with the NATO SACLANT Undersea Research Centre. Fig. 7 shows the transducers configured for in-situ depth testing early in FAF-03. Subsequently, the source-receive array was deployed as a 78 m aperture vertical array. Shown in Fig. 8 are the transducers arranged for deployment on the back deck of the R/V Alliance.

The mid-frequency source-receive array did operate effectively during FAF-03. Results from carrying out time reversal focusing over a 10 km range for a period of 55 min are shown in Fig. 9.

References

[1] W.S. Hodgkiss, J.D. Skinner, G.E. Edmonds, R.A. Harriss, and D.E. Ensberg, "A high frequency phase conjugation array," Proc. OCEANS 2001: 1581-1585 (2001).

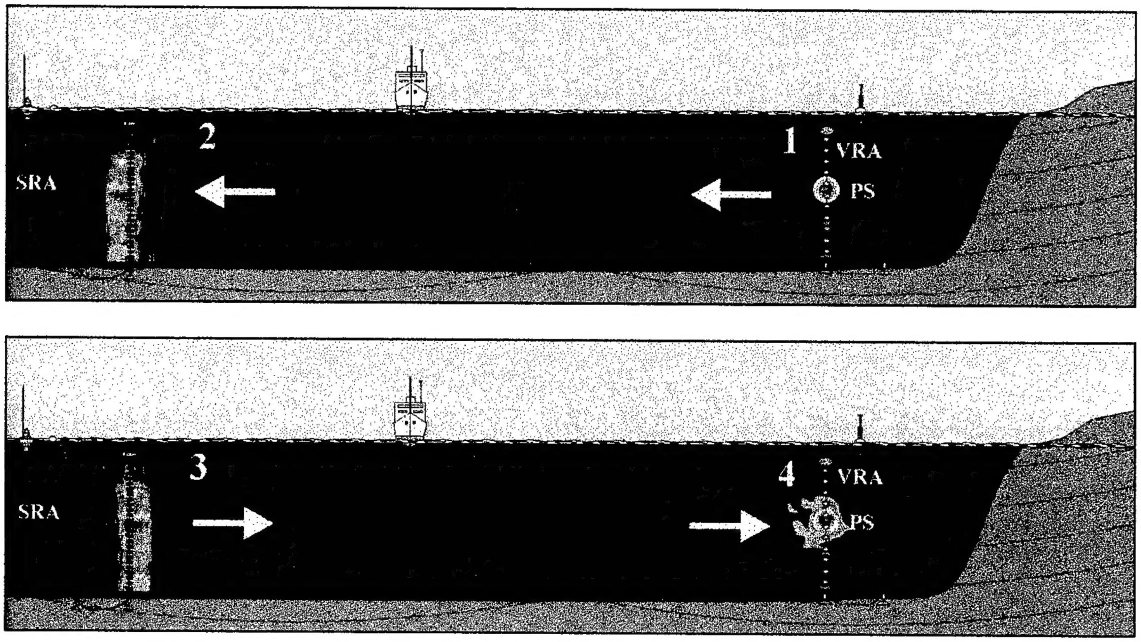

Fig. 1. Time reversal process implemented by a retransmission procedure.

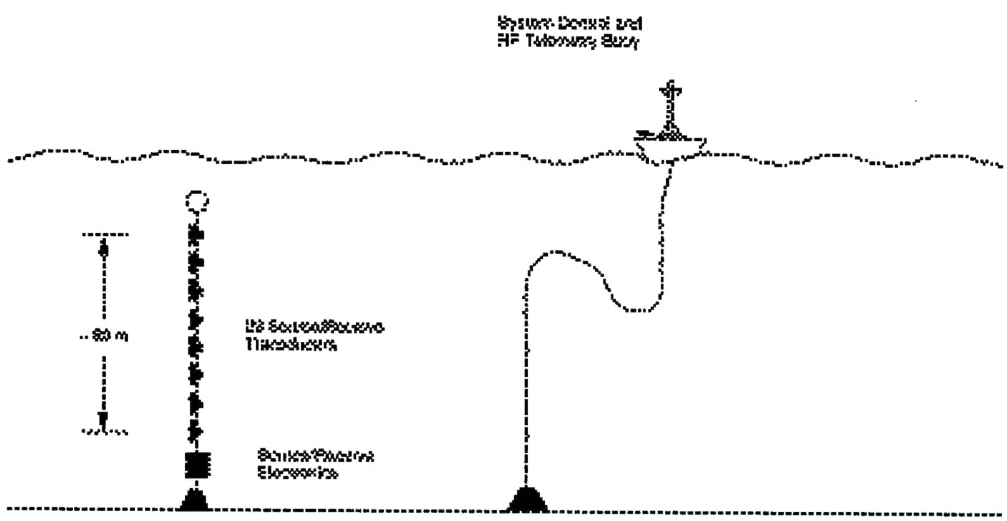

Fig. 2. Phase conjugation array system consisting of 29 source/receive transducers spanning an aperture of 78 m, an underwater pressure case containing the source/receive electronics, and a surface buoy providing battery power, system control, and wireless local area network (LAN) connectivity.

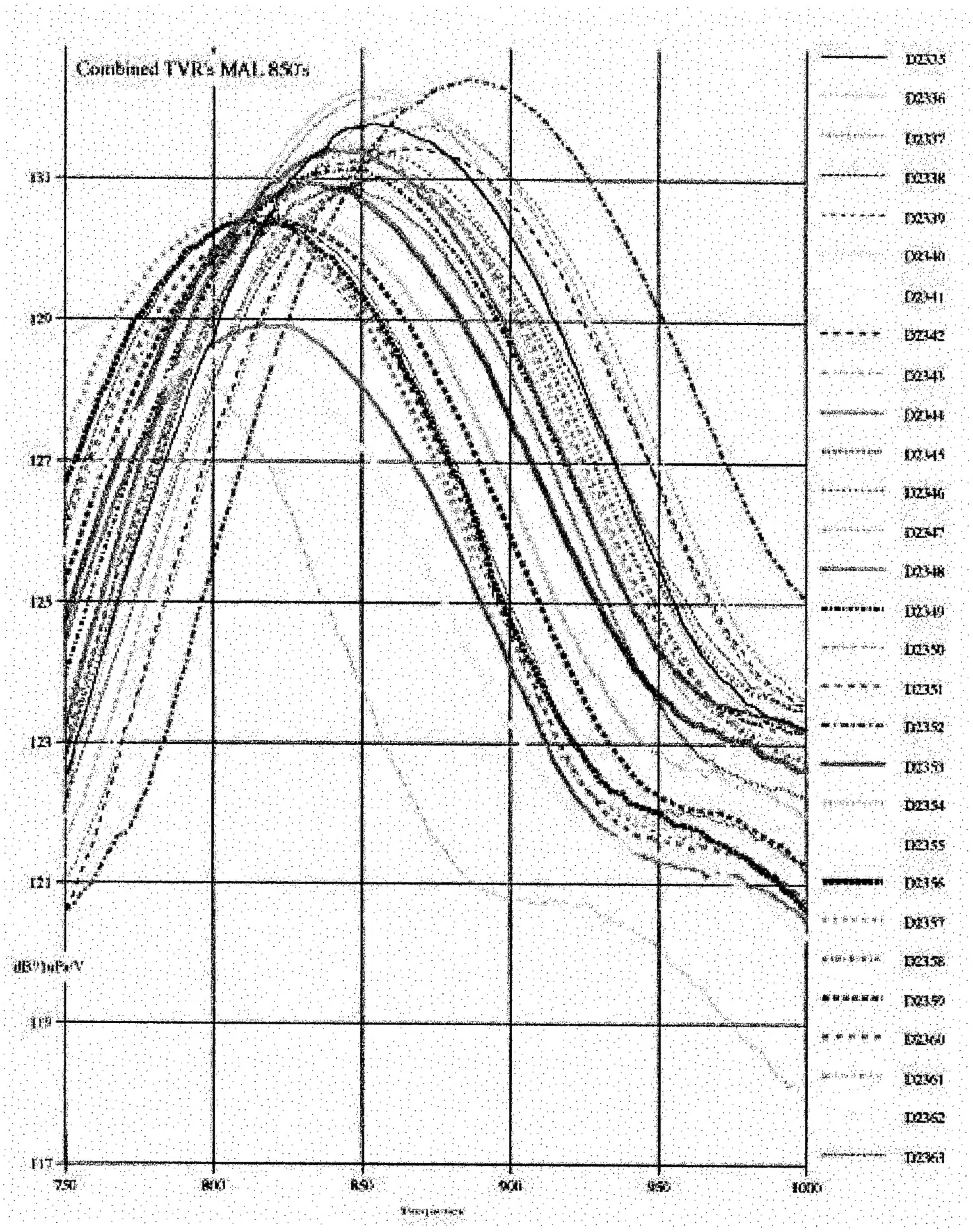

Fig. 3. Measured TVR characteristics of the mid-frequency transducer set at 12 m depth.

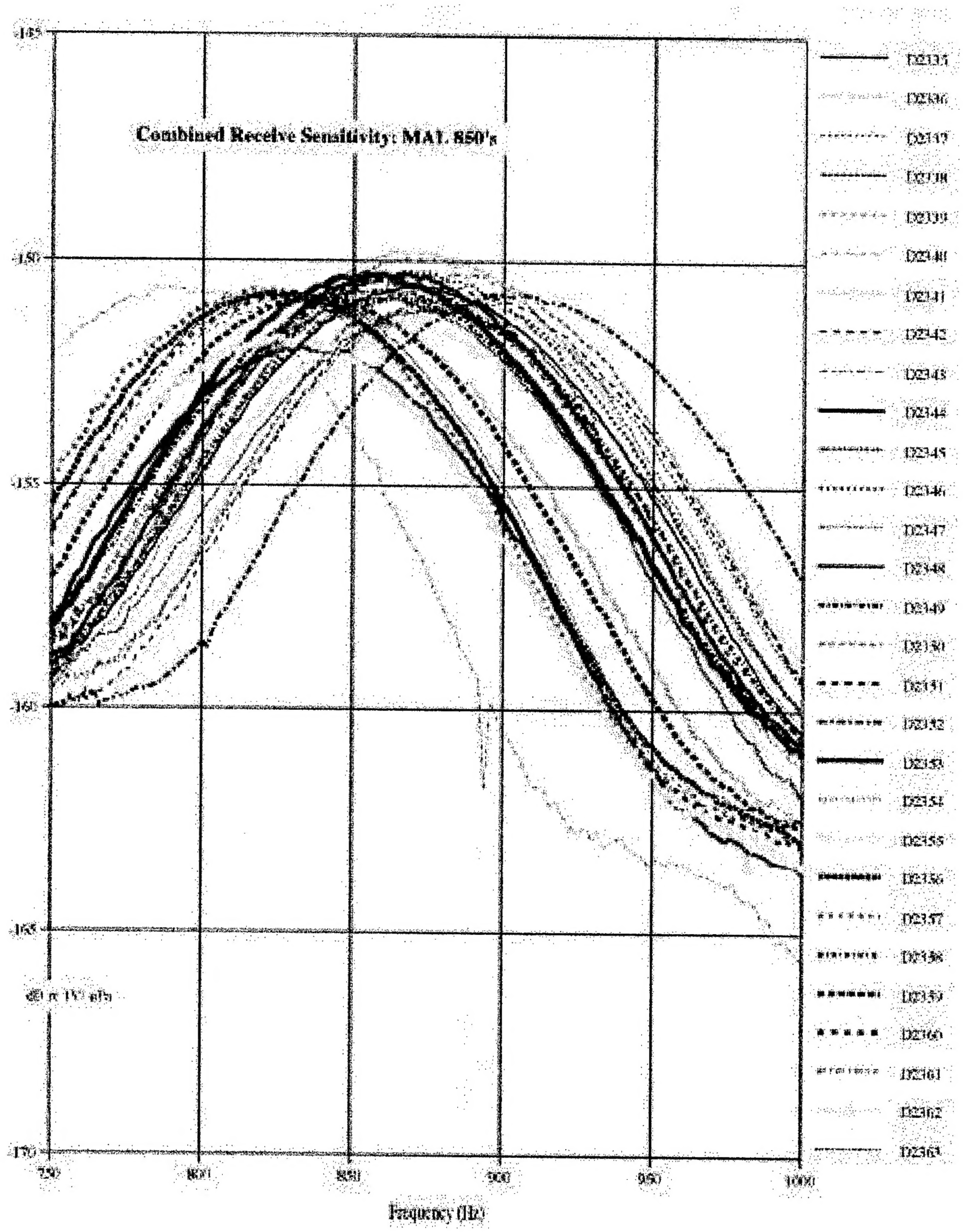

Fig. 4. Measured FFVS characteristics of the mid-frequency transducer set at 12 m depth.

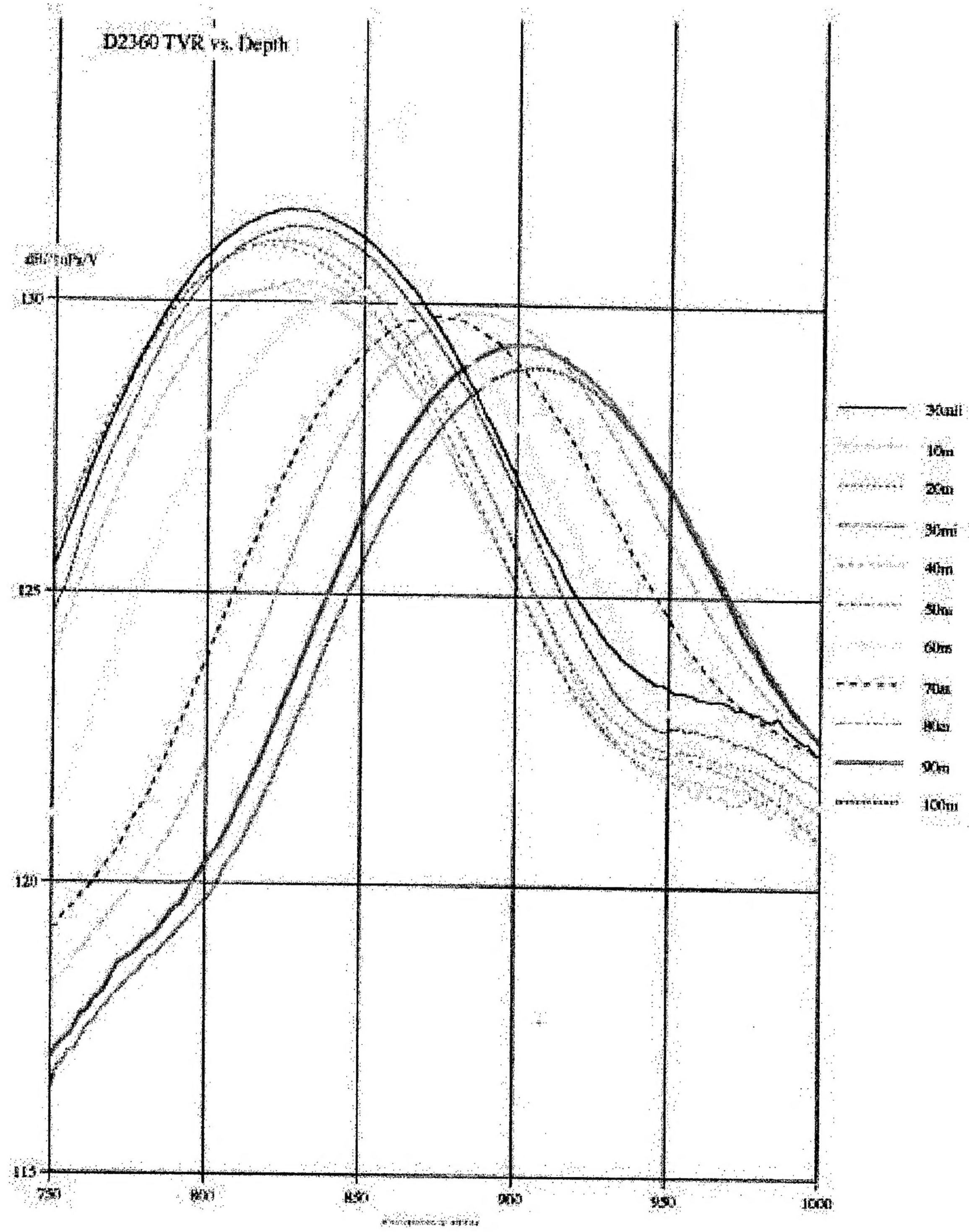

Fig. 5. Measured TVR characteristics of transducer D2360 vs. depth.

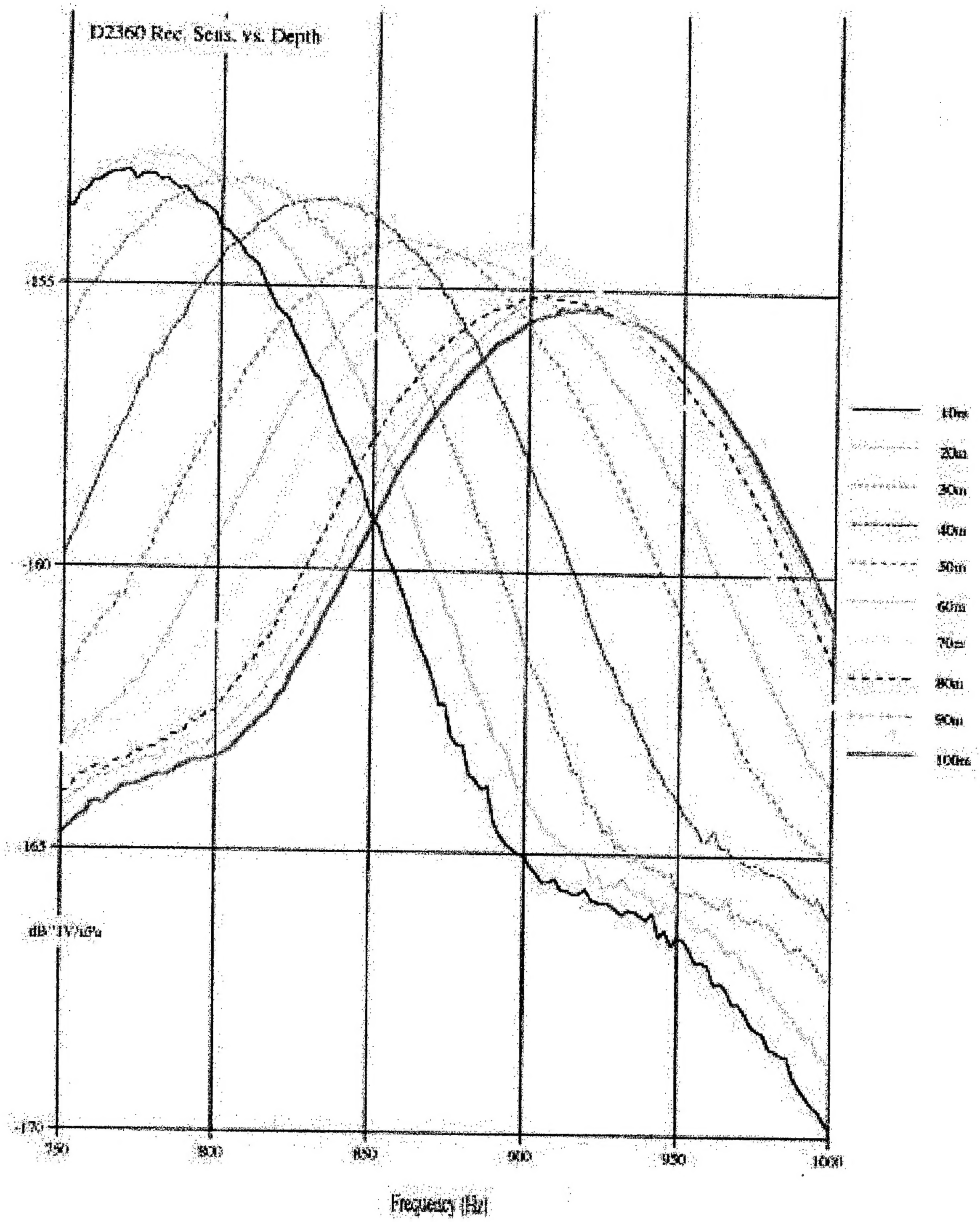

Fig. 6. Measured FFVS characteristics of transducer D2360 vs. depth.

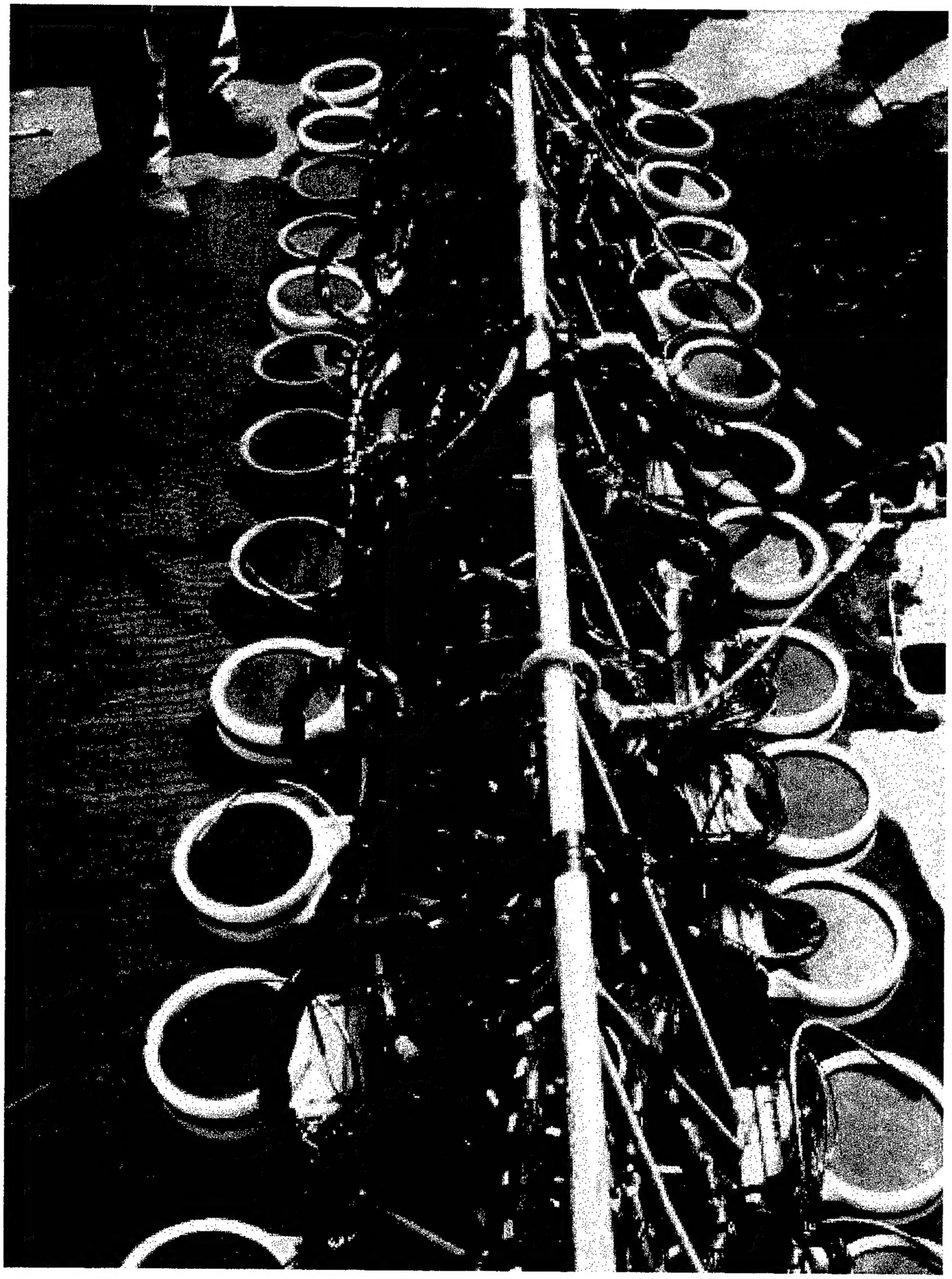

Fig. 7. Mid-frequency transducers configured for in-situ testing early in FAF-03.

Fig. 8. Mid-frequency transducers on the back deck of the R/V Alliance during FAF-03 in preparation for deployment as a 78 m aperture vertical source-receive array.

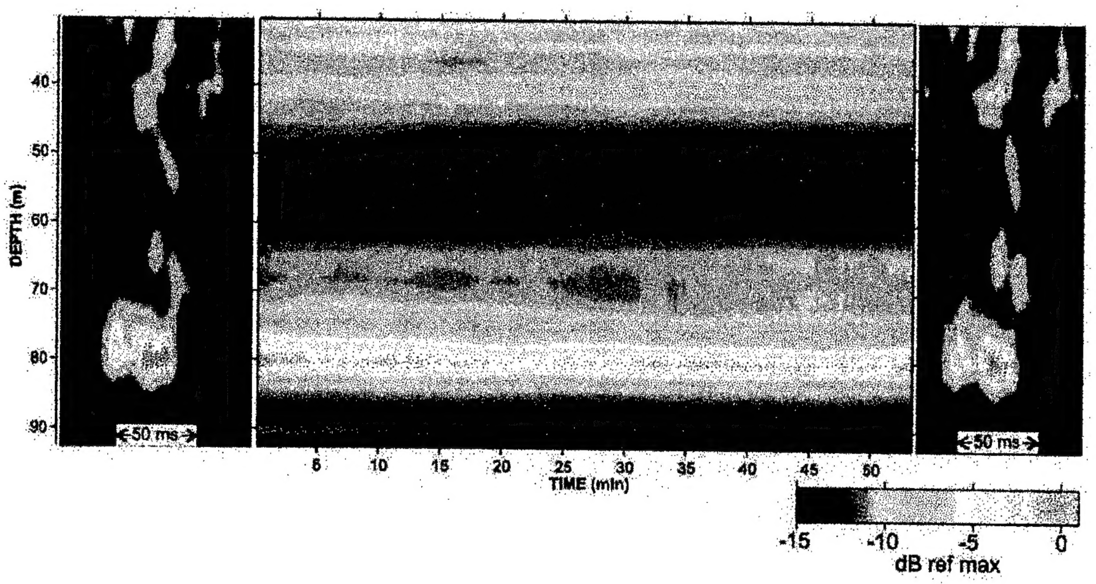

Fig. 9. Time reversal focusing during FAF-03 at 850 Hz over a 10 km range for a period of 55 min.

FUND	27018A
Agency	DN OFFICE OF NAVAL RESEARCH (ONR)
Grant Number	N00014-01-1-0799
Funding Amount	$ 161,021.00
Grant Dates	04/01/2001-12/31/2002
Budget Dates	04/01/2001-12/31/2002
Overhead Rate	M130FG MODIFIED-FEDERAL-GRANT-13.0%

Total Salaries and Benefits: 2,703.50

Sub 3 - Supplies And Expense 8,642.00

Fabrication of Mid-Frequency Source Array

MPLWH62	533	649610	72631145	3/25/02	Port Plastics	013034261	2A903285	62.00
MPLWH62	533	649610	72631145	3/25/02	Port Plastics	013034261	2A903285	800.00
MPLWH62	533	649610	72637272	4/4/02	MCMASTER-CARR SUPPLY COMP	052450259	2A870575	17.18
MPLWH62	533	649610	72654028	5/9/02	IMPULSE	0096454IN	10209709	2,507.88
MPLWH62	533	649610	72730267	11/8/02	ONESOURCE DISTRIBUTORS IN	721336001	2A935719	41.38
MPLWH62	533	649610	72730352	11/8/02	AMERICAN RIGGING & SUPPLY	005059201	2A935714	668.05
MPLWH62	533	649610	72732570	11/15/02	MCMASTER-CARR SUPPLY COMP	061106457	2A935716	17.18
MPLWH62	533	649610	72734408	11/21/02	PORT SUPPLY	000003053	2A935723	30.17
MPLWH62	533	649610	72742655	12/16/02	Falmat Inc.	000148460	2A935718	1,323.47
MPLWH62	533	649610	72748451	1/9/03	YALE CORDAGE, INC	000091492	2A935720	153.87
MPLWH62	533	649610	72748451	1/9/03	YALE CORDAGE, INC	000091492	2A935720	1,985.40
MPLWH62	533	649610	72748785	1/10/03	SOUTH BAY CABLE	000050737	10215090	323.25
MPLWH62	533	649610	72748785	1/10/03	SOUTH BAY CABLE	000050737	10215090	25,356.13
MPLWH62	533	649610	72754700	1/27/03	IMPULSE	0101538IN	10217988	5,844.36
MPLWH62	533	649610	72760359	2/10/03	NEWARK ELECTRONICS	007044700	2A949230	560.51
MPLWH62	533	649610	FMDB0113	9/30/01	MARINE ACOUSTICS LIMITED		10203711	21,792.75
MPLWH62	533	649610	FMDB0115	9/30/01	MARINE ACOUSTICS LIMITED		10203711	1,634.46
MPLWH62	533	649610	FMDB0317	2/28/02	MARINE ACOUSTICS LIMITED		10203711	64,297.80
MPLWH62	533	649610	FMDB0318	2/28/02	MARINE ACOUSTICS LIMITED		10203711	4,822.34
MPLWH62	533	649610	FRMPLD48	2/28/02	MPL SHOP LABOR RECHARGE		FAB 533	46.00
MPLWH62	533	649610	FRMPLD51	3/31/02	MPL SHOP LABOR RECHARGE		FAB 533	2,070.00
MPLWH62		649610	NIMPLAGY	10/30/02	ENPET AIR-SEA FORWARDERS, INC. 114			2,387.71
Total Fabrication of Mid-Frequency Source Array								**136,741.89**

Fabrication of Upgrade to Source Array Electronics

MPLWH62	564	649610	72704745	9/5/02	Pacific Transformer Corp	000046883	2A925614	186.41
MPLWH62	564	649610	72706911	9/10/02	DIGI-KEY 4541	012602289	2A925616	43.15
MPLWH62	564	649610	72706911	9/10/02	DIGI-KEY 4541	012602289	2A925616	556.80
MPLWH62	564	649610	72707045	9/10/02	NEWARK ELECTRONICS	006488974	2A925617	118.80
MPLWH62	564	649610	72708815	9/16/02	Pacific Transformer Corp	000047191	2A935705	13.02
MPLWH62	564	649610	72708815	9/16/02	Pacific Transformer Corp	000047191	2A935705	168.00
MPLWH62	564	649610	72710958	9/23/02	DIGI-KEY 4541	012641208	2A935709	10.63
MPLWH62	564	649610	72710958	9/23/02	DIGI-KEY 4541	012641208	2A935709	137.20
MPLWH62	564	649610	72711404	9/23/02	NEWARK ELECTRONICS	006496864	2A925618	168.46
MPLWH62	564	649610	72720437	10/15/02	NEWARK ELECTRONICS	006623377	2A925619	27.28
MPLWH62	564	649610	72726083	10/28/02	Pacific Transformer Corp	000047731	10216495	599.99
MPLWH62	564	649610	72726083	10/28/02	Pacific Transformer Corp	000047731	10216495	7,803.95
MPLWH62	564	649610	72741033	12/11/02	DIGI-KEY 4541	012943598	2A949231	31.42
MPLWH62	564	649610	72741033	12/11/02	DIGI-KEY 4541	012943598	2A949231	405.38
MPLWH62	564	649610	72741743	12/12/02	ALLIED ELECTRONICS, INC.	038602800	2A925621	127.57
MPLWH62	564	649610	72741795	12/12/02	NEWARK ELECTRONICS	006833552	2A949230	900.48
MPLWH62	564	649610	72742042	12/13/02	DIGI-KEY 4541	012956908	2A949231	28.06
MPLWH62	564	649610	72743253	12/16/02	DIGI-KEY 4541	012996182	2A949231	4.64
MPLWH62	564	649610	72743253	12/16/02	DIGI-KEY 4541	012996182	2A949231	59.89
MPLWH62	564	649610	72744478	12/19/02	SIERRA CIRCUITS, INC.	000115163	2A949229	1,832.07
MPLWH62	564	649610	FRMPLD56	8/31/02	MPL SHOP LABOR RECHARGE - AUGUST 02		FAB 564	127.50
MPLWH62	564	649610	FRMPLE60	11/30/02	MPL SHOP MATERIAL RECHARGE		FAB 564	626.48
Total Fabrication of Upgrade to Source Array Electronics								**13,977.18**

TOTAL EQUIPMENT COSTS	**150,719.07**
TOTAL DIRECT COSTS	**162,064.57**
INDIRECT COST 13% OF MTDC	**1,474.92**
TOTAL PROJECT COSTS	**163,539.49**
N00014-01-1-0799	**161,021.00**
CONTRIBUTION BY UNIVERSITY	**2,518.48**

ONR/MPL REPORT DISTRIBUTION

Office of Naval Research (3)
Department of the Navy
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660
Atten: CDR J. Tague t

Regional Director (1)
ONR Detachment
San Diego Regional Office
4520 Executive Drive, Suite 300
San Diego, CA 92121-3019

Commanding Officer (1)
Naval Research Laboratory
4555 Overlook Avenue, S.W.
Attn: Code 2627
Washington, D.C. 20375-5320

Defense Technical Information Center (4)
8725 John J. Kingman Road
Suite 0944
Ft. Belvoir, VA 22060-6218